# From Smart Meters to Smart Products: Reviewing Big Data driven Product Innovation in the European Electricity Retail Market

Nicolai Krüger[1], Frank Teuteberg[2]

**Abstract:** This paper tries to provide a perspective on energy informatics that goes beyond solely technical research. Combining the viewpoints of energy informatics and information systems in a review of top-ranked literature, we aim to start the discussion how to bridge the gap between a technology-driven focus on big data possibilities (such as smart grid, smart metering, etc.) and a business model-driven perspective (innovation, price-reduction, CRM, etc.). With this paper we further underline the necessity of an interdisciplinary research approach and try to investigate a value chain-oriented implementation of big data initiatives. Especially in the European electricity branch, big data – in terms of smart metering – seems in some cases to be implemented in order to fulfil governmental regulations. CRM as well as corporations' change management has been neglected. By conducting a structured literature review, the status quo of smart meter related big data (initiatives) in energy informatics and information systems will be discovered, and a research agenda for further research in this area will be provided.

**Keywords:** Big data, change management, big data implementation, smart metering, smart grid, energy informatics, data-driven business, data-driven innovation.

## 1 Introduction and broader research scope

### 1.1 Linking big data, change, product innovation and smart metering

Initiated by the European Union's directive on energy efficiency [Eu06], energy providers were obligated to offer demand-based price packages for electricity to consumers, which gave big data the potential to reach every single European household: Typically big data is defined by the 4 V's, volume, velocity, variety and veracity [Go14][MB12]. Measured with smart meter devices (veracity), any electricity consumption will cause data (volume) that needs to be transmitted from the end-user to the energy provider (velocity) [SK12][MRT12]. Matching the smart meter data with additional information resources of the consumer, e.g. weather conditions, would offer energy providers a huge variety of data to create smart and consumption related pricing packages [REG10]. But while the EU's regulations have been fulfilled by launching

[1] University of Osnabrueck, Accounting and Information Systems, Katharinenstr. 1, 49069 Osnabrueck, Germany, an@nicolaikrueger.de
[2] University of Osnabrueck, Accounting and Information Systems, Katharinenstr. 1, 49069 Osnabrueck, Germany, frank.teuteberg@uni-osnabrueck.de

smart grids, smart meters, and a variety of big data technologies to offer individual price ranges for consumers, the real potential of data-driven business models did not become the core focus for electricity providers, as a T-Systems survey among 250 managers in that branch discovered in February 2013: 47% of the interviewees do not see the value within data, even if they see an annual data-growth-rate of 25% [TS13].

Abstracting the given example, the question of how big data should be implemented has become more relevant today, compared to the questions asked in the past regarding whether or not large-scale and high frequency data existed and which mathematical patterns and predictions could be engineered with it. Therefore this paper focuses on reviewing the status quo in energy informatics (EI) and information systems (IS) regarding the combination of three elements: big data, change/product innovation management and smart metering. Smart metering, which is defined by German energy industry law as a "measuring device […], which reflects the real energy consumption of each user and the real time of consumption" [En10], represents a concrete modulation of the broader research ambition of the authors: to find out how big data and change/innovation processes in organizations can be handled, e.g. whether product managers of energy providers shall become more like data scientists or vice versa. We stress this topic to underline that in fact, most of the research done so far in science has been technologically initiated. Nevertheless, some authors (especially [KSB13] and [Go14]) have already pointed out the necessity for a more social-, business model- or user-oriented science approach within the field of EI to enable individuals and institutions to handle the potential opportunities (and through that, upcoming changes and innovations) presented by these technologies. In this context, we understand change management primarily in the classical view of Kotter, to prepare a corporation for new circumstances within the market [Ko12]. Furthermore, chances of relying on big data (and in this context, of smart metering) may also limit the potential for disruptive innovations with completely new solutions for problems [Ch13].

### 1.2 Research question

Within this overall frame, EI in general and smart meters in particular also offer an interesting research subject, combining the perspectives of technology, legal regulations and business models. Beyond our literature review, we are going to create a research agenda to point out which steps in science need to be taken to enrich the instruments of EI and IS due to this purpose.

The search term "big data" indicates a significant development in the Google Trend analysis (cf. figure 1, case sensitive search for all submitted queries worldwide between 2006 and 2015), which we introduce here as an additional indicator for the substantial growth of interest and publications on that topic. Google Trend normalizes all conducted searches between a scale from 0-100 by comparing a specific search query to the total amount of searches; therefore the Y-axis below can be understood as a general search trend over time.

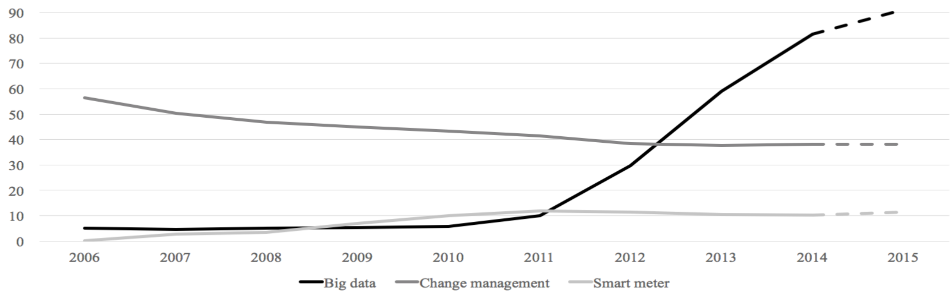


Figure 1: Google Trend indicates an increasing interest in big data

The chart also follows our above argument, that during the same timeframe the interest in the search query "change management" did not increase. Looking at the keyword "smart meter," a constant interest seems to be in place since 2011.

After presenting a wide scope of different perspectives on our topic, we can summarize our research with two specific questions:

*RQ1: How can change and product innovation management enable the effectiveness (e.g. in terms of cost-savings or additional turnover) of big data initiatives?*

*RQ2: Which change and product innovation management enablers (e.g. communication, transformation strategy and so forth) can be applied for smart metering within EI?*

To answer those two questions, we conduct a systematic literature review to investigate the status in EI/IS science and to draw a future research agenda. The paper is structured as follows: In section 2 the underlying research methodology is described. We present a quantitative analysis afterwards in section 3, including a discussion of open questions based on the studied papers. Section 4 provides a practical perspective on our topic by discussing selected cases from today's energy market in Europe. Finally, section 4 also points out which limitations we faced during our creation process and provides – as a main deliverable of this paper – a research agenda.

# 2 Research methodology

## 2.1 Systemic literature review and analyzed articles

Based on a systemic literature review process (cf. figure 2), the authors intend to follow a broadly accepted framework [Br09], which starts with a scope definition (see introduction), resulting in a conceptual keyword list. To focus only on results with high impact on the topic given, the following 16 search queries have been designed as Boolean match types: *big data implementation*, *big data and change management, big data and value chain, big data and business model, big data and decision making, big data and success factor, big data and customer relationship management, big data and* *product development, big data and service development, big data and organizational change, big data and hr, big data and CRM, big data and human resource*, *big data and electricity, smart meter and value chain* and finally *smart meter and product innovation*.

In another step, the authors selected 23 A-ranked journals for research purposes, which was also based on a generally accepted journal ranking [WK08]. For the database search, EBSCO (Academic Search Premier, Business Source Premier and Regional Business News), SpringerLink, ScienceDirect and Google Scholar have been used. Additionally, we included the three top ranked IS conferences (ECIS, ICIS and WI) and entered the accompanying articles via AISeL with the same keyword-structure as used for the journal research.

Within the forward/backward search, our approach aimed on staying close to the research topic. Therefore the same quality premises for the initial search have been taken. Additionally, with the purpose of keeping a narrow perspective on the research subject, either the keyword "big data" or not predefined but impactful aspects must have been visible. In order to keep the quality of the source selection model described above, the criteria publication timeframe, journal respective conference working has also been used while executing the forward and backward literature search.

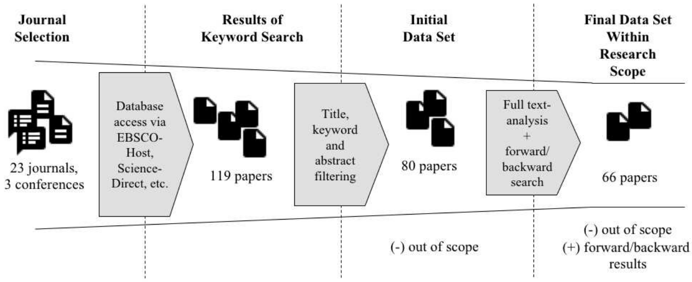


Figure 2: Funnel view of the research methodology

## 2.2 Related work

Within the research result we found three related articles which are summarized in tab. 1: One article provides a literature review about EI, pointing out that EI move beyond the solely technological aspects. The other two articles tried to answer the question, how big data initiatives can return value to an organization.

| | |
|---|---|
| Title, Reference, Method | "Energy informatics. Current and future research focus." [Go14], review based approach |
| Publications reviewed | No explicit period; books, articles, proceedings |
| Research objective(s) | Creating an overview about the status quo in EI, especially intelligent energy saving systems and smart grids |

| | |
|---|---|
| Results | ▪ Sensors and corresponding software are the key for smart grid technology and future developments<br>▪ EI shall include a market-oriented perspective, taking economic, psychological and sociological aspects into account – this can be achieved by focusing on systems and mechanisms to increase energy efficiency and by integrating renewable energy sources into the power grid |
| Title, Reference, Method | "Business intelligence and analytics: From big data to big impact" [CCS12], review based approach |
| Publications reviewed | Approx. 2002 - 2012, academic and industry publications |
| Research objective(s) | Reflecting the impact of data-related problems in corporations |
| Results | ▪ Structured literature review of almost one decade research framework to identify emerging big data methods<br>▪ Analysis of applications, data, analytical methods and potential impact for five branches |
| Title, Reference, Method | "Creating value with business analytics in the supply chain" [SB13], case study |
| Publications reviewed | No explicit period; books, articles, proceedings |
| Research objective(s) | To use the resource-based view and dynamic capabilities for implementing business analytics into a company's value chain |
| Results | ▪ Implementation framework for business analytics into an organization from a resource-based view<br>▪ Governance, change management, organizational learning, BA-enabled innovations and hybrid skills are important to gain value from big data |

Tab. 1: Summary of related work

While the related papers focus either on a combination of the research perspectives big data and change/innovation or big data and smart metering, our paper will try to bring all three aspects together (cf. figure 3). As every related paper already offers a high value and well structured systematic for each viewpoint, our review is going to define a deep dive route through published articles and proceedings with a combined perspective on it.

# 3 Analysis of results

## 3.1 Research focuses of analyzed papers

The original search results of 119 articles have been reviewed based on their titles, keywords and abstracts in order to filter out those papers without any relation to our research. In the next step, the 80 remaining articles were analyzed in detail. Some additional cases have been excluded within this step, as the content and applied methods in those articles did not correspond with the assumption based on keywords and abstracts; for all others, a significant fit to the given topic has been found and a forward-/backward search has been executed. All in all, this approach generated a data set of 66 articles, which will be examined in detail in the following sections. By filtering our result list of 66 articles by topic, a clear picture of the focus of each article can be generated. This indicates once again that big data in combination with change/innovation has already been the focus of previous research. Nevertheless, a combined view of smart metering and one or both of the other IS centric views show potential for further research activities.

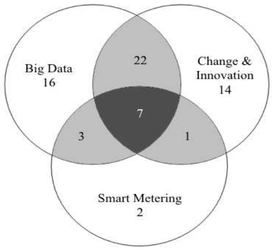


Figure 3: Overlapping and solitary research focuses found

### 3.2 Quantitative and chronological result analysis

The amount of published articles over time follows the trend of search queries on Google (cf. figure 4): At the time of producing this article, the 2015 level has already reached the total level for 2012. Almost 70% of the selected sources have published corresponding research between 2006 and today, distributed in a total of 15 journals respectively published at one of the three top ranked conferences.

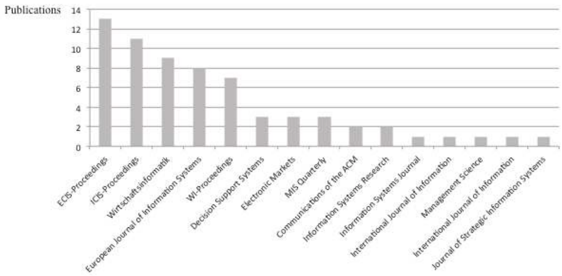


Figure 4: Accumulated result per journal/conferences (ranked by results per journal)

### 3.3 Research perspective of analyzed papers

To understand the meta-layer of each paper in a more detailed way, we selected four different perspectives based on an adapted PEST-analyze [FN86]: Papers with a clear technical (we added mathematical) perspective formed one cluster, those with a clear economical perspective a second one. Articles with an organizational (we added social) view formed a third cluster. Finally, those articles with a broad perspective on the general orientation of their scientific discipline form the last cluster.

| | 2006 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| Technological/ Mathematical | | 1 | 1 | 1 | 1 | 2 | 2 | 4 | 4 |
| Economical | 1 | | 2 | | | 2 | 6 | 3 | 2 |
| Organizational/ Social | 1 | 2 | 2 | 2 | | | 4 | 7 | 1 |
| General Science | | | | | | 3 | 6 | 6 | |

Tab. 2: Research perspective of analyzed articles over time

Between 2006 and 2011, the majority of articles focused roughly on big data in terms of large and high frequency data-modulation within ERP projects, business analytics and intelligence and as well on change, innovation or implementation aspects. Looking on the general articles in our research scope, like [Go14b], [NM14] or [KSB13], it becomes clear that more and more, journal and conferences call for specific research according our research questions. While there has always been a technical or mathematical interest in our research topic, only latest research tries to provide a cross-disciplinary approach: For instance in [Ha15a] the authors analyze the digital transformation effects of primarily physical industries.

### 3.4 Applied research methods of analyzed papers

We analyzed the methods used by each paper to understand the development, status quo and possible gaps for a future research agenda. For this step, we followed a classification of research methods by Wilde and Hess [WH07]. The diagram below shows that empirical methods are used quite often in the analyzed articles, because papers like [FSN12] or [Wa13] selected a very specific problem to be solved with statistical models.

We would like to highlight the case studies in [KB14], where big data implementation into decision-making processes has been analyzed: The result, that the role definition of an enabler/integrator is necessary in the practical field correspondents with our finding of a research gap in science. In [Bu13a] the conducted interview goes more into detail, carving out that a mixed skill set of IT-tools, statistical education, but also a strong feeling for profitable business models will be required.

In terms of smart metering and the question how to utilize this from an economical perspective, two papers ([WBN15] and [AZ14]) offer initial studies into this direction. Under the economical aspect, general big data studies provide wider and more empirical research (e.g., in terms of supply chain benefits [SB13] or in the direction of data-driven business models [LG09], [OA13] and [Ha15a]).

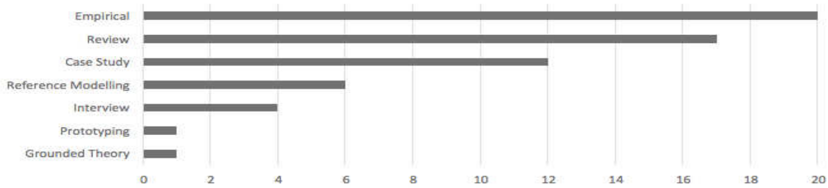


Figure 5: Research methods applied

The analysis is limited by the fact that not all authors specifically introduced their research methods. In those (minor) cases we tried to identify the chosen path and method of the authors by studying the presented approach and results. Nevertheless, a methodological test or validation was not in our scope.

### 3.5 Outcome: Problems to be solved

Following our used methodology from the previous two sections, we studied the open problems and research questions of each paper. We are going to highlight the main topics and representatives of each group in tab. 3.

| Perspective | Problems to be solved | References |
|---|---|---|
| General science discipline | • Implementation of data-driven thinking into the different disciplines (EI/IS)<br>• Further discussion of moral and ethical questions like data privacy necessary | [Bi13], [Bu13b], [Wo14] |
| | • Curriculum adaptations for a data-driven but also environmental-driven education<br>• Combination of social, technological, data- and business-driven viewpoints | [Bi13], [AD14] |
| | • Finding a guiding viewpoint for EI specific articles<br>• Implementing an interdisciplinary perspective into EI | [Re14], [KBK12], [Go14b], [KSB13] |
| Technological/ mathematical | • Data protection and privacy in terms of smart metering<br>• General quality assurance in big data initiatives | [SK12], [ESB10], [LRI14], [HH14] |
| | • Potential of matching smart grids, smart meters, electric vehicles and other decentralized sources<br>• Future data availability and effectiveness for steering of smart grids | [BF14], [SK12], [Kr15], [KW15], [KBK12] |
| Economical | • Value creating implementation of smart metering into energy retail organizations | [AZ14], [BWN12], |

| | | |
|---|---|---|
| | | [KBK12] |
| | • Future business models for data aggregators, collecting and using data from smart meters and offering their infrastructure for data processing to electricity retailers | [BF14] |
| | • Descriptive metrics not only regarding the change of one company, but also the change of an ecosystem of companies through digitalization | [Bh13] |
| | • Optimization of the intraday electricity purchase by predicting capacity and usage of renewable energies and electric vehicles | [BFN13] |
| | • Granting value added to consumers based on smart metering | [WBN15] |
| Organizational/ social | • Upcoming behavioral risks through big data | [Ol14] |
| | • Reduction of implementation costs of big data initiatives | [BH08], [By10] |
| | • Handling decision processes in organizations, which become more complex through big data | [Bu13a] |
| | • Cultural / language influences on skill profiles of big data experts | [DMV14] |
| | • In-depth case studies / expert interviews on digitalization of physical industries | [Ha15a] |
| | • Definition of role, skills and implementation plan of an analytical integrator as bridge between decision makers and data scientists | [KB14] |
| | • Motivating employees for creative use of data and stimulating data-driven thinking | [KLS14], [AD14] |

Tab. 3: Overview of open problems and questions

# 4 Implications and outlook

## 4.1 Practical implications: Current trends in the field of smart metering

Based on a simplified approach of data triangulation [Fli11], we will add a practical view to the research we conducted. While the quantified review perspective before offered a structured path through related science of the last years, the chosen second perspective may also support timing and practical relevance of our topic.

As the lawmaker pushes smart metering, energy suppliers started already many initiatives to provide measuring devices for instance to private households. At this point we refer once again to Kotter's fundamental definition of change management, which aims on preparing corporations for new market circumstances [Ko12]. Those market transformations are – based on the BITKOM association – already visible in the electricity branch and they will change the relationships between consumers and suppliers fundamentally, empowered by big data: The consumers' market position will be strengthened by transparency about their own consumption, while supplier and retailer will face a data-driven change in their business model [Bi13].

The consulting company PWC identified key steps to handle the transition from the classical energy- to a modern service-provider, which summarizes our findings with regards to RQ1: As a primarily step, the overall business model and strategy needs to be adapted due to the digital transformation of the branch. Afterwards, the organizational change has to be conducted. This will take effect in recruiting and job scopes for example, because new skills are necessary to work in a service-oriented company instead of working for a classical energy supplier. In a third step the implementation into the core processes of the company must take place, i.e. by creating a service center [PW13].

Vestas Wind can be taken as a possible path for energy enterprises to react on RQ1: The energy supply company was able to identify the initial problem (wind forecasting) as a big data challenge. By gathering weather data from internal and external sources, a weather library with 24 petabytes of data has been created. Referring to tab. 3 (especially [BFN13]), Vestas faced as well the challenge how to monetize the data. Two approaches were implemented: Earning savings within the intraday market through better wind forecasts and a change in the investment strategy for new wind turbines by using more precise geographical prediction of the wind flow. This example underlines our economical and organizational outcomes of tab. 3: Although the technical enhancement seems to be a fundamental step, Vestas' management faced the barrier of a value-oriented utilization of the additional data [IB11].

This barrier, which can be described more precisely as the gap between data science and corporate decision-making, is also an outcome of Kowalczyk's and Buxmann's research and puts an additional aspect to RQ1 [KB14]: In a multiple case study, big data & BI experts have been interviewed about past and running big data initiatives. In general, an effective integration of data-centric decisions requires domain specific knowledge of the decision maker on the one hand and the communicational expertise, analytical understanding and visualization skills of an integrator on the other hand – as also discussed in section 3.4. The definition of that role from an integrated ES/IS perspective might also form a starting point for further research.

Beside that interpersonal or cultural aspect, another case study about the use of sensor data discovered a process related cornerstone for big data implementation: Organizations must prepare their own processes for insights which might come up through big data. In the given case study, people were able to mark potholes on the rode in a mobile device app. The GPS-based data grew so fast, that the pilot city Boston was not able to handle the following processes [OL13]. Applying this lesson learnt to RQ2 and to the energy market, where retailers still struggle to predict consumers' energy consumption with classical volatility models – i.e. without sensor based and individual data [FSN12] –

retailers' business models and core processes must get prepared for a smart meter and data-driven direction.

### 4.2 Research implications: Elements of a research agenda and conclusion

Returning to our two research questions, we asked how big data could generally, and in terms of smart metering more specifically, enable change and innovation. By presenting a selection of current real world cases it became clear, that those questions are posed at the right time and – following the interdisciplinary approach – into the right direction. Furthermore we outlined a possible implementation and change management path for big data driven products in the electricity branch.

As every research paper has its limitations, we would like to point out that by selecting a cross-disciplinary perspective, not every reviewed paper can offer a combination of all three perspectives (big data, change/innovation and smart metering). Therefore, we suggest primarily further research to identify the scope of the problem. Another limitation arises through the practical real world cases which we included into section 4.1, which where not purely based on academic literature but also on industrial publications.

The literature review that we conducted within this paper shall be followed by further in-depth case studies. In that step, as well as during the empirical study, other branches with experience in data- and sensor-driven businesses might also be reflected. For instance, automakers are facing a quite similar discussion regarding connected cars right now. During the second step, the conceptual phase, a reference model and a business maturity model shall be developed which can be tested and improved empirically in the third step [BKP09]. In regular frequencies the previous research shall be reflected – e.g., action research can deliver additional insights for this or new case studies can be conducted.

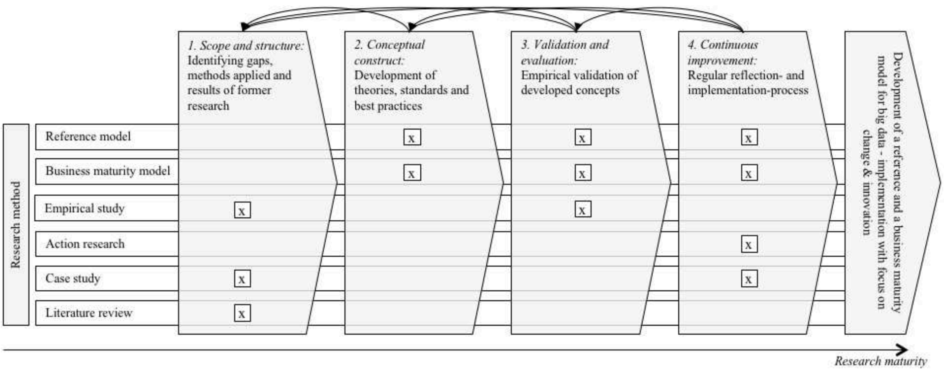


Figure 6: Elements of a research agenda, based on [MF09]

## References

The complete reference list, including the 66 articles analyzed in our literature review, is available on: http://goo.gl/AZdSIs


[Bi13] BITKOM: Management von Big-Data-Projekten. Leitfaden. Available on https://www.bitkom.org/files/documents/LF_big_data2013_web.pdf, downloaded on the 31st of March 2015.

[BKP09] Becker, J.; Knackstedt, R.; Pöppelbuß, J.: Developing Maturity Models for IT Management. Business & Information Systems Engineering, 1(3), P. 213–222, 2009.

[Br09] Von Brocke, J. et.al.: Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. ECIS-Proceedings, Verona 2009.

[Ch13] Christensen, C.M.: The innovator's dilemma. When new technologies cause great firms to fail. Boston, 2013.

[En10] Energiewirtschaftsgesetz – EnWG §21c: Gesetz über die Elektrizitäts- und Gasversorgung. Einbau von Messsystemen, 2010.

[Eu06] European Union: Directive 2006/32/EC of the European Parliament and of the council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC, 2006.

[Fli11] Flick, U.: Triangulation. Eine Einführung. Wiesbaden, 3rd Edition, 2011.

[IB11] IBM: Vestas. Turning climate into capital with big data. Available on http://www-01.ibm.com/common/ssi/cgi-bin/ssialias?infotype=PM&subtype=AB&htmlfid=IMC14702USEN#loaded, downloaded on the 6th of April 2015.

[Ko12] Kotter, J.P.: Leading Change. Massachusetts, 2012.

[MF09] Martens, B.; Teuteberg, F.: Why Risk Management Matters in IT Outsourcing - A Systematic Literature Review and Elements of a Research Agenda. ECIS-Proceedings, Verona 2009.

[OL13] O'Leary: Exploiting big data from mobile device sensor-based apps: Challenges and benefits. MIS Quarterly Executive, 12(4), P. 179–187, 2013.

[PW13] Smart Metering. Intelligente Messsysteme für die Energienetze von morgen. Available on http://blogs.pwc.de/auf-ein-watt/files/2013/08/Smart_Metering-Intelligente_Messsysteme_f%C3%BCr_die_Energienetze_von_morgen.pdf, downloaded on the 31st of March 2015.

[TS13] T-Systems International GmbH: Energie durch Big Data. Sind Europas Energieversorger für das Datenzeitalter gerüstet? 2013.

[VB09] Von Brocke, J.; Simons, A.; Niehaves, B. et.al.: Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. Retrieved February 25, 2015.

[WH07] Wilde, T.; Hess, T. (2007). Forschungsmethoden der Wirtschaftsinformatik – Eine empirische Untersuchung. Wirtschaftsinformatik, 49 (4), P. 280-287, 2007.

[WK08] WKWI: WI-Orientierungslisten. Wirtschaftsinformatik 50 (2), P. 155-163, 2008.